Pioneer Work of the Telluride Power Company

By P. N. Nunn

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By P. N. Nunn

In the light of present achievements in high-tension, long-distance electric power transmission, the early work of the Telluride Power Company, fourteen years ago, and further developed in the immediately succeeding years, commands unqualified admiration. It was work of daring enterprise, pioneer work in the face of discouraging comment from almost everywhere, making its successful outcome all the more gratifying to those who undertook it, and interesting to the profession generally. Mr. Nunn's account of it was given for the first time in a paper presented at the recent International Electrical Congress at St. Louis, and its publication here, embellished by many additional illustrations, has been made possible through his kind co-operation.—The Editor.

THE ORIGINAL POWER HOUSE AT AMES, 1890

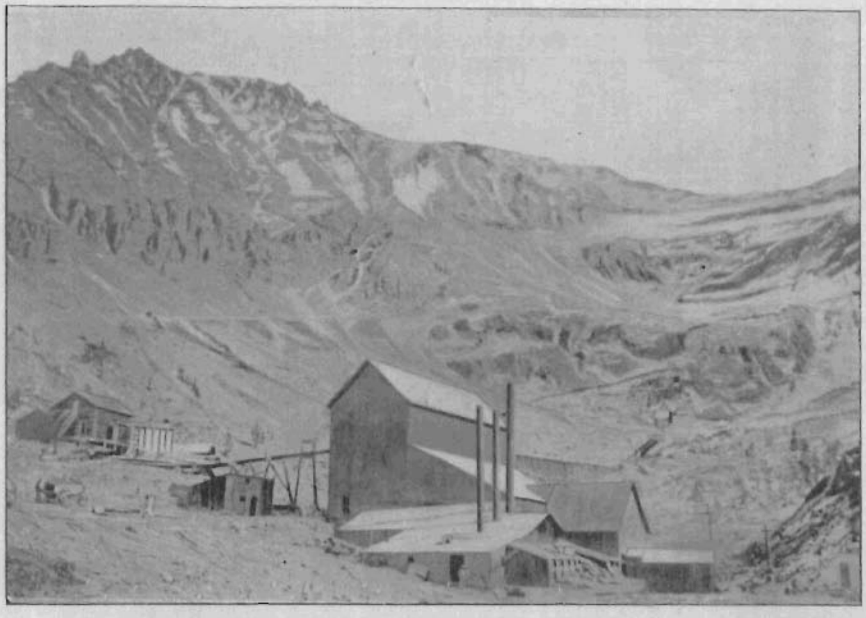
During the winter of 1890, the year preceding the famous Frankfort-Lauffen experiment, apparatus was installed for the first commercial, high-pressure, alternating-current power transmission of the world. From that beginning has grown The Telluride Power Company.

The mining district surrounding Telluride, Colorado, is at the same time one of the most rugged and one of the richest in the Rocky Mountains; but its inaccessibility and the consequent cost of producing power caused the financial failure of many important enterprises in the early days of its history. The statement made in the Annual Report of the Treasury of the United States, in 1901,* that "For the growth of its mining industry San Miguel County is indebted to The Telluride Power Transmission Company more than to any other agency," is borne out by the fact that at the present time all the important mines and mills of the district are operated by power furnished by this company.

The Gold King mill, situated at an altitude of 12 000 ft., where the cost of fuel for steam power had become prohibitive, was the first to be operated by means of this power. This

*Annual Reports of the Treasury of the United States. Report of the Director of the Mint, page 135.

A VIEW OF TELLURIDE, COLORADO



GOLD KING MILL, IN WHICH THE FIRST SYNCHRONOUS MOTOR WAS USED

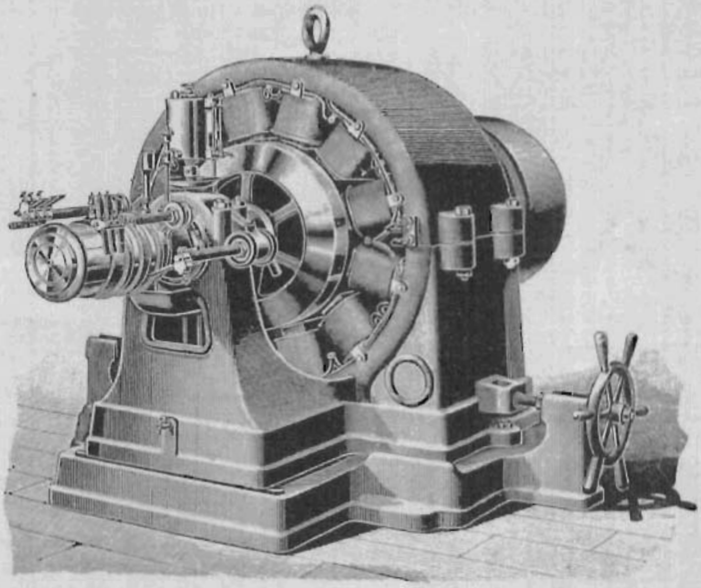
property had been attached in 1888 to satisfy a continued deficit in operation, due to the excessive cost of power, whereas a handsome profit would have been realized had power been secured at not to exceed a hundred dollars per horse-power-year.

Down in a deep gorge of the valley, over 2 000 ft. lower, but less than three miles away, two mountain streams formed at their confluence the South Fork of the San Miguel River, offering cheap and continuous power. A stay of proceedings was secured; and, as means of transmitting this power, cable drive, compressed air and continuous-current electricity were successively investigated. The limitations of each were apparent, while the advantages of alternating current and higher pressure became gradually recognized, and a decision was reached to attempt their use. This decision was due less to the immediate saving in copper than to a keen sense of the limitation of continuous current, and faith in the final success and ultimate superiority of alternating current.

During the investigation which followed, while selecting apparatus, little but incredulity or ridicule was encountered. Eastern investors in the enterprise were annoyed by the predictions of prominent engineers, and discouraged by their insistence, that the experiment would prove a miserable failure and the expenditure go for naught. It was said that there was no alternating-current motor; that oil insulators must be used and that the line must be fenced in. However, a generator and a motor for 3 000 volts and of 100 h.p. each were ready for trial in the fall of 1890. Difficulties caused by ice at 40 deg. below zero, by speed control over unusually high water pressure, by avalanche, by blizzard, by electric storms unknown in low altitudes, and scores of other difficulties now generally forgotten but then most serious, marked every step of progress. Notwithstanding all of these, unqualified success from the beginning caused gradual and constant growth, until at the present time The Telluride Company and its allied industries have six power stations and

GENERAL VIEW SHOWING AMES WATER POWER AND ITS LOCATION nearly a thousand miles of line in Colorado, Utah and Montana.

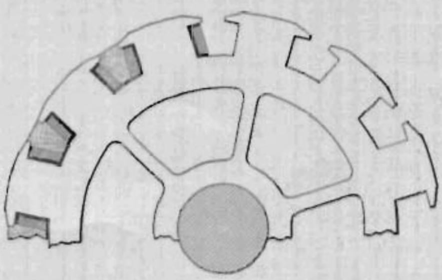
Following its pioneer power transmission, it made practical experiments as early as 1895 with pressures which



THE EARLIEST ALTERNATING-CURRENT GENERATOR FOR POWER SERVICE

have never, even yet, been exceeded; and for three years it operated commercially the highest-pressure transmission of the world. Thus the record of its work becomes an important chapter in the history of power transmission; but it must readily be seen that the limit of this paper precludes the possibility of describing even in briefest terms, all, or even a substantial part, of its pioneer work.

The initial installation, purchased through Mr. F. B. H. Paine, comprised a generator installed in a rough cabin upon the site of the present Ames station and belted to a 6-ft. Pelton wheel under 320-ft. head, and a motor at the mill 2.6 miles distant. The two were identical Westinghouse single-phase alternators of 100 h.p., the largest then made. The generator was separately excited, while the motor was self-exciting. Both carried twelve-part commutators and were slightly compounded through current transformers upon opposite spokes of their armatures. The latter were iron clad, or "T"-toothed, wound with twelve simple coils in cells of fuller-board and mica. Switchboards were matched and shellacked pine sheathing, and the bases of instruments were dry hardwood. Only voltmeters and ammeters were used, both of the solenoid and gravity-balance type, in black-walnut cases with window-glass fronts. Circuits were closed with jaw switches and opened by arc-light plugs. The line carried two No. 3 bare copper wires mounted upon short



SECTION OF "T"-TOOTHED ARMATURE WITH THREE COILS IN PLACE

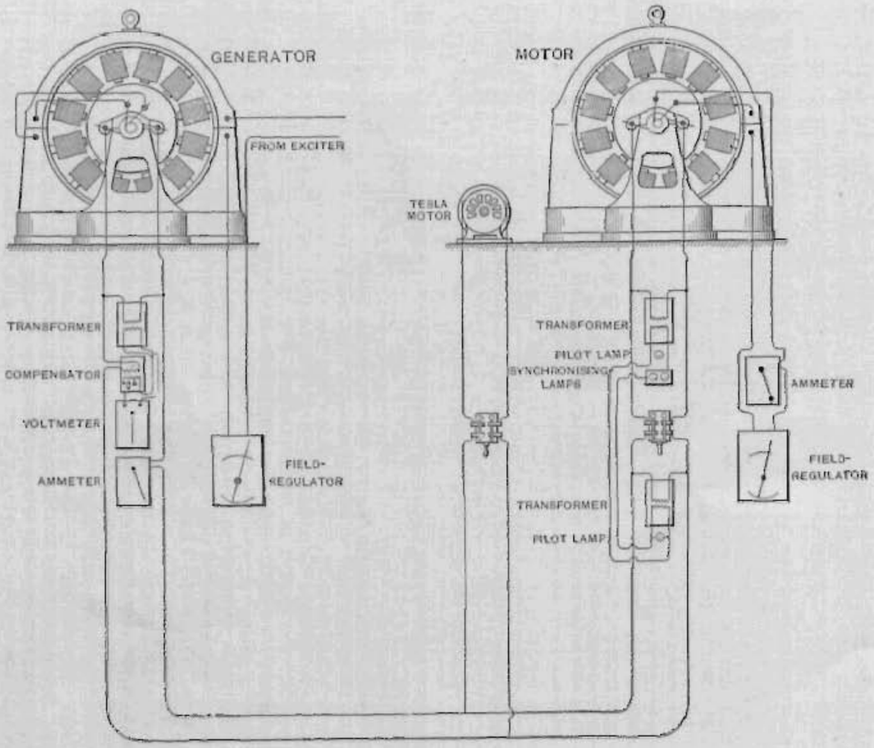


DIAGRAM OF ORIGINAL SYNCHRONOUS MOTOR SYSTEM AT TELLURIDE

Western Union cross-arms and insulators. The copper cost about $700, about one per cent. of the estimated cost for continuous current.

The main motor was brought to synchronous speed by a single-phase induction starting motor, which received its current at full line voltage. The current taken was more than full-load current of the main motor. Even this starting motor required starting by hand, its torque being zero at starting and so feeble at low speeds that when cold it could only with the greatest difficulty be persuaded to pull up to speed its belt and loose pulley. Nor could it at speed start the main motor without help, and even then it became so hot that its short-circuited secondary frequently burned out.

Another motor of 50 h.p. was soon added. While in other respects similar to the first, this motor was intended to be self-starting, with armature and field in series through current transformer; and on account of its frightful flashing, it was fitted with a special eight-part commutator of non-arcing metal. This feature, however, proving a failure, was soon replaced by a separate starter.

The need of wattmeter or power-factor indicator not having been at that time recognized, motor field charges were adjusted for least main current. This current was accepted as having unity power factor, and, therefore, as the measure of actual power.

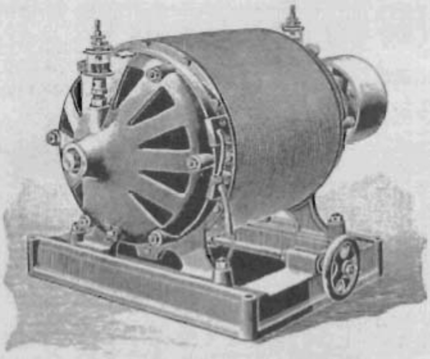
Everything was extremely simple from water wheels to motors; and, except for lightning, the plant ran smoothly and steadily thirty days and more without a stop. The report made in the East by associates of the enterprise that at Telluride a hundred horse power was being successfully transmitted nearly three miles over

No. 3 copper, with less than five per cent. loss, was received with the utmost incredulity.

During the autumn of 1892, a 600-h.p. generator of the same characteristics was installed, and a 250-h.p. motor for the mill on Bear Creek, ten miles from the generator. Early in 1894 a 50-h.p., and during the fall a 75-h.p. motor were placed in Savage Basin, fourteen miles from the power house. The former was soon replaced by a 100-h.p. motor, and in 1895 another 100-h.p. motor was set up at Pandora.

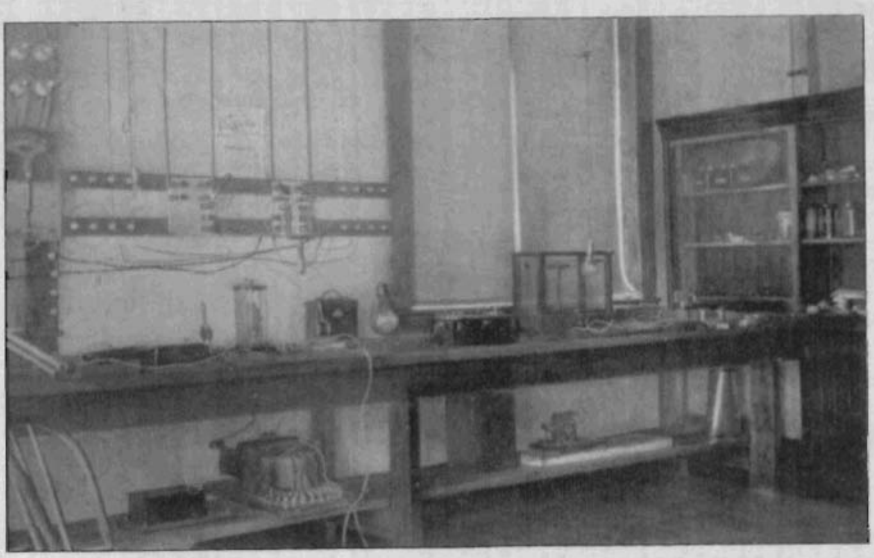
Except as to size these motors were substantially identical. The 250-h.p. motor was badly designed, and the pole pieces were of cast iron. Its starting motor was insufficient, and was, therefore, soon replaced by one having split-phase secondary with external resistances. Marble bases with brass trimmings replaced wooden bases for instruments, and such elegance demanded highly polished slat switchboards of paraffined oak.

Imposing marble rheostats were mounted at switchboards like manuals upon grand organs. Fuse blocks, the only protective devices, became marble slabs with duplicate aluminum strips. The first synchrophone came with the 75-h.p. equipment.



TESLA STARTING MOTOR

Owing to its altitude and geographic position, the Telluride district is peculiarly subject to atmospheric disturbances. Over a hundred distinct lightning discharges have been counted within a single hour, and such occurrences caused more discouragement than any other obstacle. A neighboring continuous-current plant, transmitting but little more than a mile, carried several extra armatures; and even then it was so frequently compelled to close down during the daily storms of the rainy season, that the company was eventually bank-

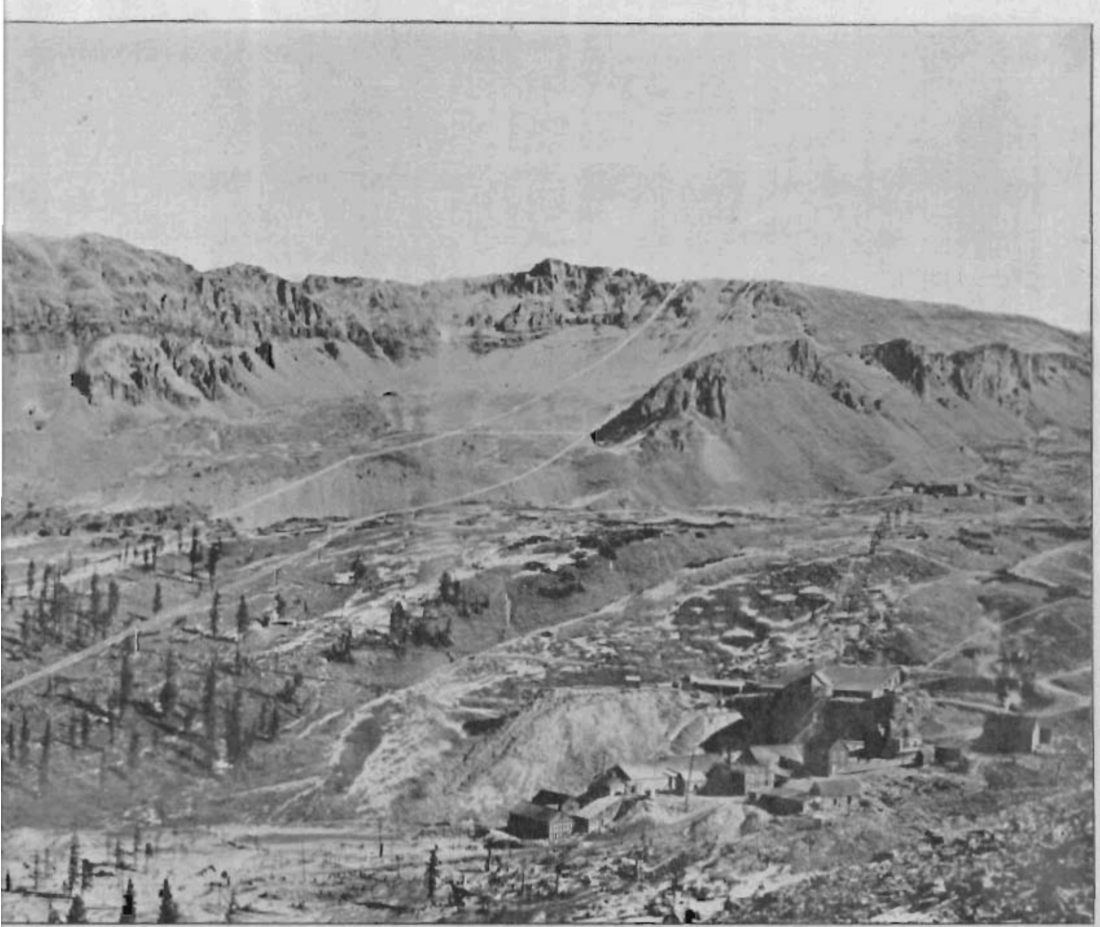


THE EARLY LABORATORY FOR STUDENTS

GENERAL VIEW OF SAVAGE BASIN, SHOWING THE TOM

rupted. The alternating plant might have suffered a similar fate, had it not been for its "T"-toothed armatures and replacable coils, eight of which were successively burned out and replaced on one motor within a single week. To place a coil and drive its keys home, required such bending, clamping and pounding as inevitably resulted in injury to insulation, and only by the greatest care could replaced coils be made to withstand a test adequate to the 3 000 volts employed. For protection from lightning several types of manufactured arrestors, then various home-made devices were tried, ending with a simple gap in series with a score or more of fuse blocks in parallel, arranged about a radial commutator switch turned from point to point as the fuses were blown by successive discharges. From the first these conditions caused the greatest apprehension as to the commercial success of electric power transmission, until Mr. Alexander J. Wurts, during a stay of several months with the company, gave the protection of his now well-known non-arcing arrestor.

No transformers were used between machines and line, the largest transformers at first being 2-kw., or 40-light. Aside from the effects of lightning, even to-day 3 000 volts upon the winding of small high-speed arma-



BOY, JAPAN AND OTHER PROPERTIES AND CAMP BIRD DIVIDE

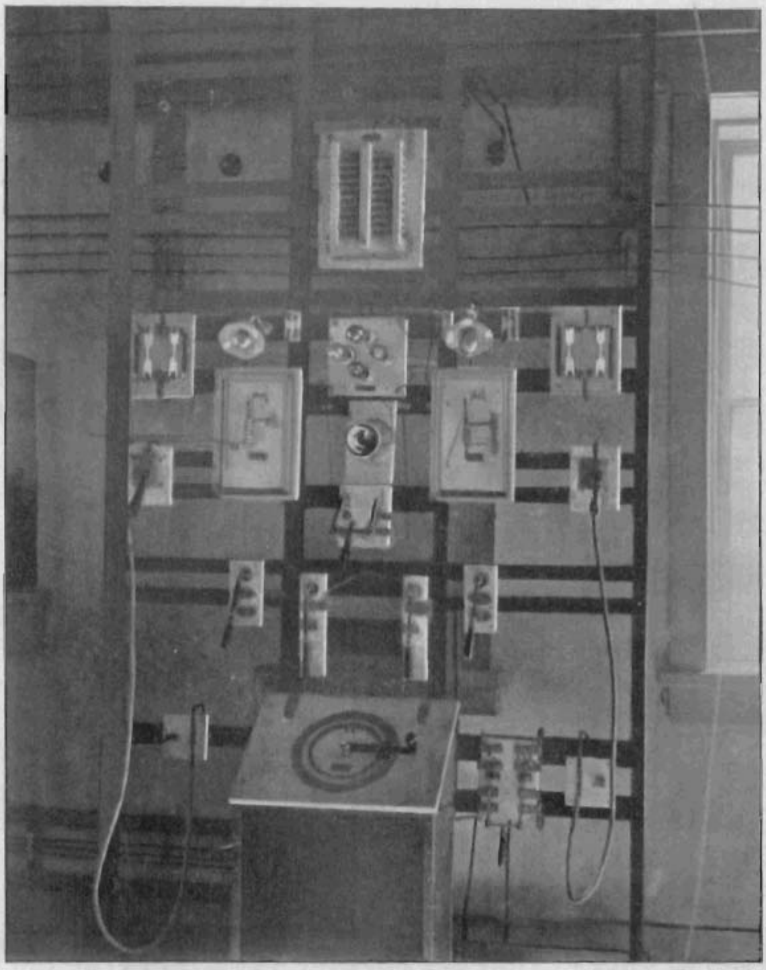
tures requires first-class insulation. Frequent grounds were prevented by deep insulating foundations of paraffined wood. To prevent short circuits within the coils, their cells, just before placing, were poured full of shellac, and the entire armature afterward baked for several days. By this means the 50-h.p. motor ran without trouble for a full year in a room dripping with moisture.

A lightning transformer received in 1891, was rated at 5 kw. Theretofore transformers had been rated in lights, and generators in horse power. This transformer was immersed in engine oil, and marked an epoch in the company's history. Lightning frequently punctured it, causing its fuses to blow without other apparent injury. It remained in service for years. All others were soon likewise immersed. Four 500-light, dry Stanley transformers, purchased in 1892 for lighting Telluride, were broken down by the thunder storms of the following spring. When repaired they also were immersed in engine oil, and gave no further trouble during the three years they remained in service.

Alternators were paralleled at Telluride in the spring of 1893, and thereafter they were so operated with full load upon the smaller and regulation upon the larger machine.

Manipulation at switchboards or at

THE ILIUM POWER HOUSE

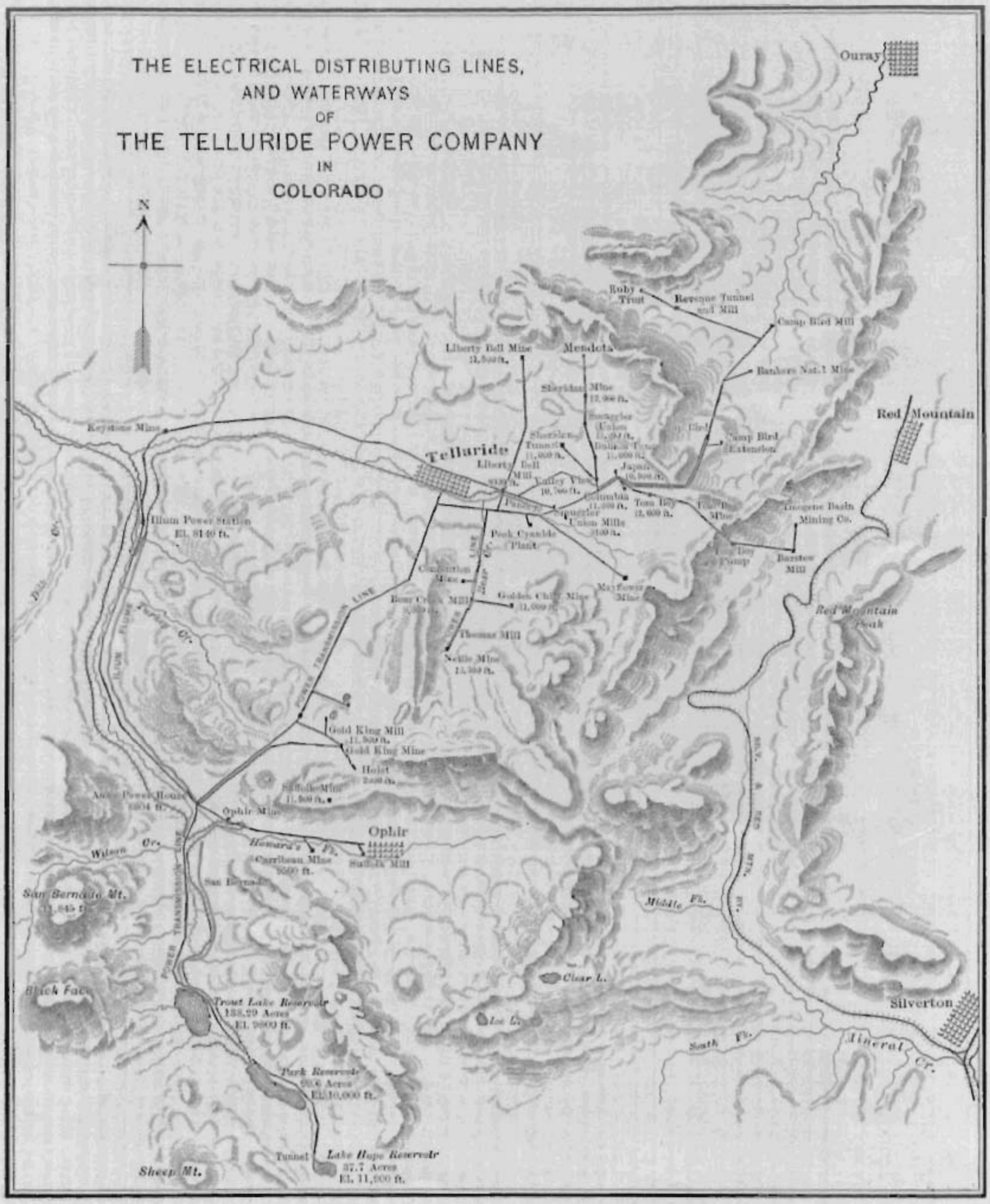


ONE OF THE MOTOR SWITCHBOARDS OF THE TELLURIDE SYNCHRONOUS SYSTEM

brushes involved direct handling of 3 000 volts, a rather high switchboard pressure even now. It was a rule that every attendant should keep one hand in his pocket while working with the other. It is pleasant to record that during these years no loss of life and but few accidents occurred.

There being no other circuit breakers, it was necessary, when a motor dropped out of step, to break the circuit with the single arc-light plug. This always drew a heavy, vicious arc, which on the big motor frequently held to the full length of the 6-ft. cable, and then sometimes required a "whiff" from the attendant's hat. When not broken promptly it frequently involved the entire switchboard and shut down the plant.

Duties of this nature required considerable skill and cool heads, and in order to operate the plant continuously, night and day, fifteen or twenty competent attendants were required. To fit young men for these positions a course was arranged during which they were taught something of machinery; of shop work in metal and wood; and of wiring, insulating and repairing, while receiving such assistance in daily study as conditions per-



THE ELECTRICAL DISTRIBUTING LINES, AND WATERWAYS OF THE TELLURIDE POWER COMPANY IN COLORADO mitted. A technical library, including the electrical papers, and a conveniently fitted testing room were always open. Each student was then given a short laboratory course in graphic treatment of alternating-current theory. This is said to have been the first systematic effort made by a corporation of this nature to train its employees for responsible positions.

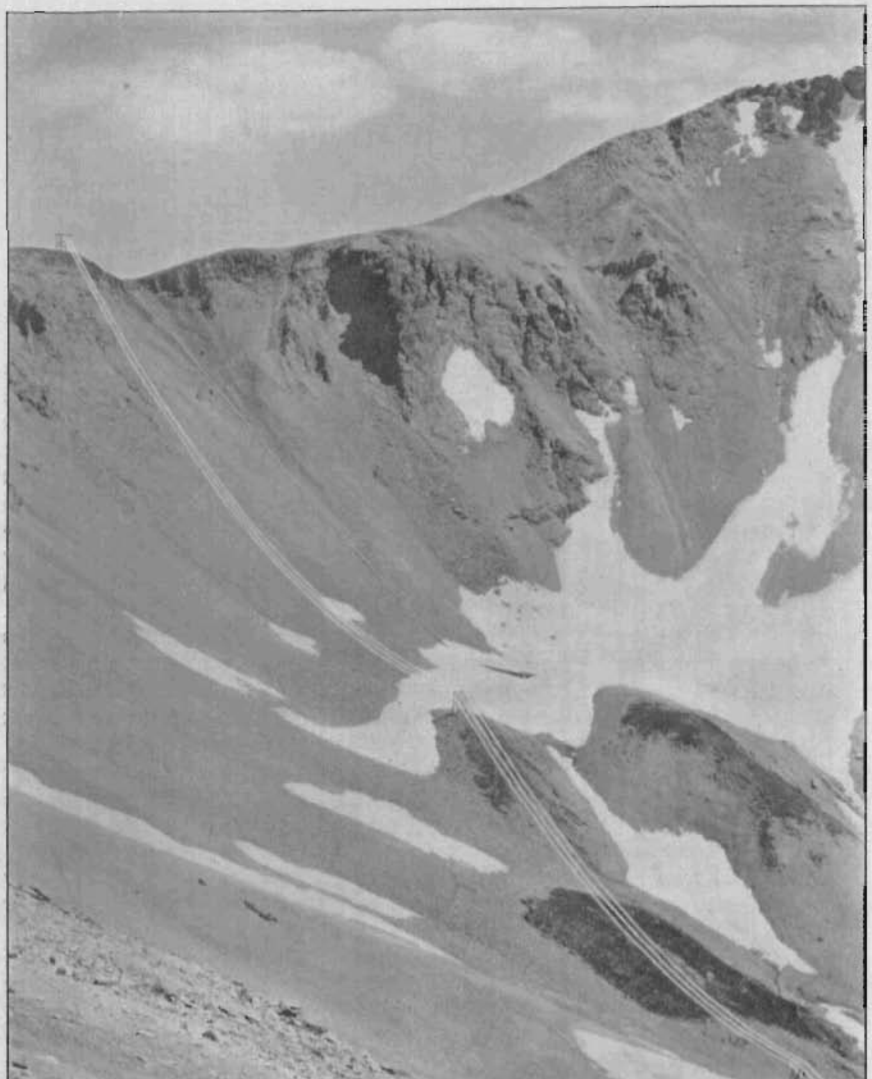
Although the plant as a whole was an unqualified commercial success, no explanation need here be made as to why its apparatus was replaced by the induction system as soon as the latter had been perfected. This marks the limit of the most extensive single-phase, synchronous plant ever operated. With one or two motors its operation was not difficult; but each motor added to the system brought increased demand for care and skill. The causes of difficulty were not understood then as now, nor was the effect of power factor fully appreciated. Lack of both wattmeters and power-factor indicators left the adjustment of field charges to the judgment of the operators. The power factor of each motor being dependent not only upon its own adjustment but upon that of all, the closest attention and co-operation were necessary, in marked contrast with the simplicity of operation of induction motors. Disturbances due to starting motors were especially trying; and the unqualified success attained, notwithstanding defects of apparatus and system, is attributed now, far more than then, to the skill and vigilance of the operators in this new and fascinating field.

The Tesla system, substituted for the synchronous in 1896, comprised two 600-kw., 60-cycle, 500-volt, two-phase generators, direct connected to water wheels under 600 and 900-ft. head, respectively, and an equal capacity of raising and reducing transformers and of two-phase, 220-volt induction motors. The twelve 100-kw., step-up transformers were connected in pairs, two-phase-three-phase, for three-phase 10 000-volt transmission. These transformers were worthless; all broke down within a year, and one or more were always undergoing repairs. Break-downs occasionally caused sufficient explosion to lift a cover or splash the oil. The woodwork soon became saturated, and hot metal from the near-by main fuses frequently started fires endangering the wooden power-house. A masonry transformer-house in two compartments was therefore constructed, and into it the transformers were moved—this being the first known case of isolation of oil transformers on account of fire risk.

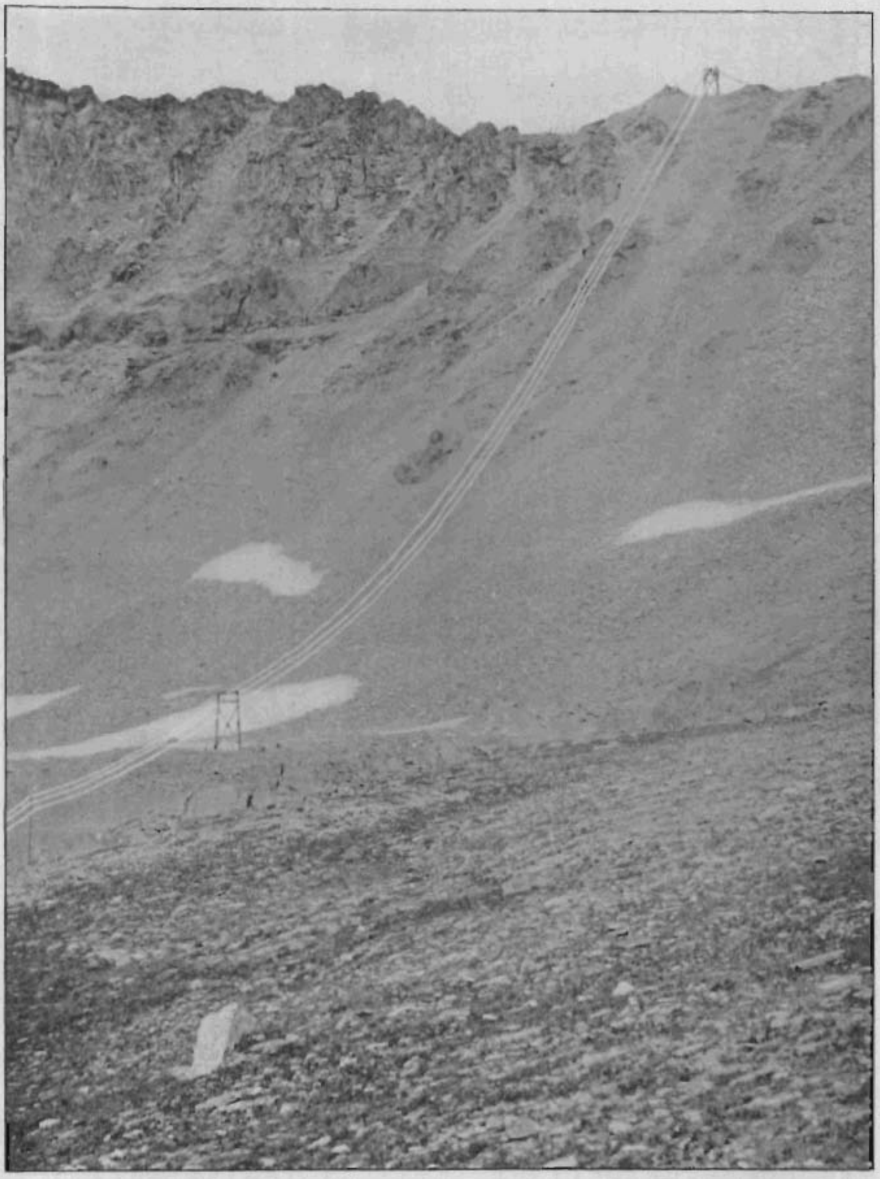
The power house at Ilium, situated 6 miles below Ames on the same stream and using the same water, was built in 1900, and contains one 1 200-kw., revolving-field, General Electric generator direct connected to two impulse wheels under 500-ft. head. Transmission lines extend both to the Ames station and to points of distribution, providing the insurance of duplicate transmission. Any section of line can be cut out for repair, or either power house shut down, without interrupting the service. Junctions, other than generating and distributing points, are equipped with open-air switches mounted upon standard line insulators and operated from platforms similarly insulated.

Junction houses at distributing centers provide for a branch line to each customer, which is equipped with switches, fuses and a set of five record-making instruments—a voltmeter, two ammeters and two wattmeters. The power company thus secures upon its own property a continuous, accurate and satisfactory record of each load.

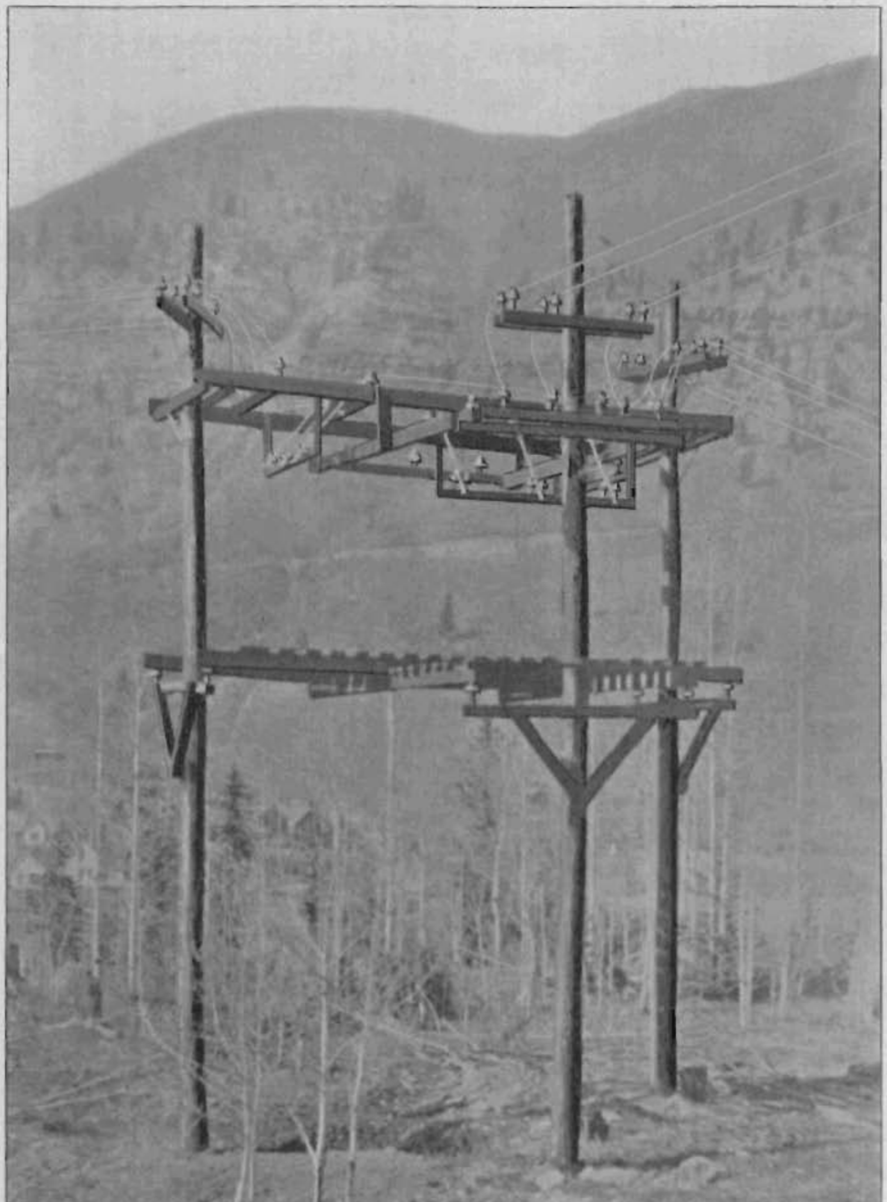
The long spans crossing canyons and divides surrounding Savage Basin are worthy of note. These divides are bare ridges at an altitude of 13 000 ft., inaccessible in winter and swept by frequent snow-slides. Spans up to 1150 ft. are used in order to reach safe points for supports. A number of these supports, although simple and inexpensive, have stood for years without repair. The longest span is of No. 1 hard-drawn copper,



A LONG SPAN AT RED MOUNTAIN DIVIDE



ANOTHER LONG SPAN AT CAMP BIRD DIVIDE



AN OPEN-AIR SWITCHING JUNCTION

supported by half-inch plow-steel cable, both carried by the same insulators. The deflection is approximately 35 ft., on a slope of 31 deg. Another is of $\frac{3}{8}$-in. soft-iron cable, 1 120 ft. long, and has been in service five years. A third, 660 ft. long, is of hard-drawn copper only, having 25 ft. deflection. The strain insulators in all cases are a series of the usual line insulators and pins, upon a longitudinal arm hinged to permit adjustment to span motion. They are simple, inexpensive and entirely successful.

A 10 000-volt underground transmission was put in operation at the Gold King mine in 1896. Power was carried through an unused tunnel 1 300 ft. long, upon bare copper conductors 12 in. apart on standard line insulators, to a deep-mine hoist equipped for electric power. The tunnel was always dripping with water; but although slight brush discharge or halo was at times observed, no trouble was experienced during the several years of operation.

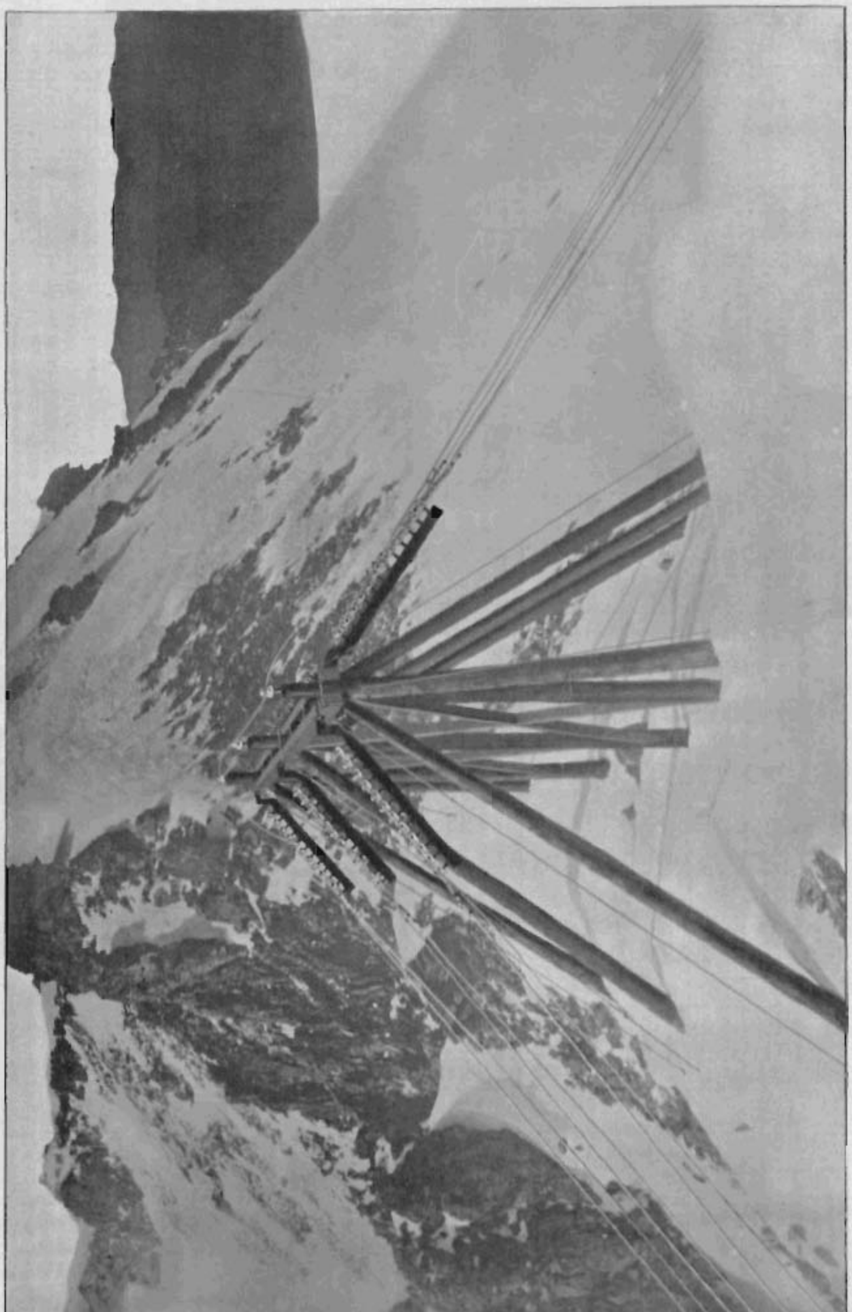
An interesting installation to which power is furnished is that of the well-known Camp Bird, near Ouray. Nineteen rotaries and motors, in sizes up to 150 kw., drive crushers, Huntingtons, concentrators, compressors, pumps and hoists, aggregating about 1 000 kw. Two under-ground transmissions, each a mile in extent, are in operation. Continuous current at 550 volts from two rotaries and from a 650-ampere-hour storage battery operates three deep-mine hoists of 150 h.p. An installation designed by Mr. C. S. Ruffner, now engineer of the Utah department, makes use of alternating current transmitted at 10 000 volts through paper-insulated, lead-covered cable, for the purpose of operating two 50-h.p. pumps.

The success of the original plant prompted the manager of the company, Mr. L. L. Nunn, to institute a search for other water powers in the West, showing as a result that such powers were remote from available markets, requiring much longer transmissions than theretofore used. Voltages higher than 10 000 to 15 000 were not in commercial use, and were regarded as merely problematical. Two important water rights, already acquired in Utah and Montana, would, however, have been worthless at such pressures. Mr. Nunn, therefore, determined in 1895 to undertake at Telluride an experimental transmission at higher voltages, to be installed and operated as a practical test for power purposes, and to ascertain if possible the problems peculiar to long distances and high pressures.

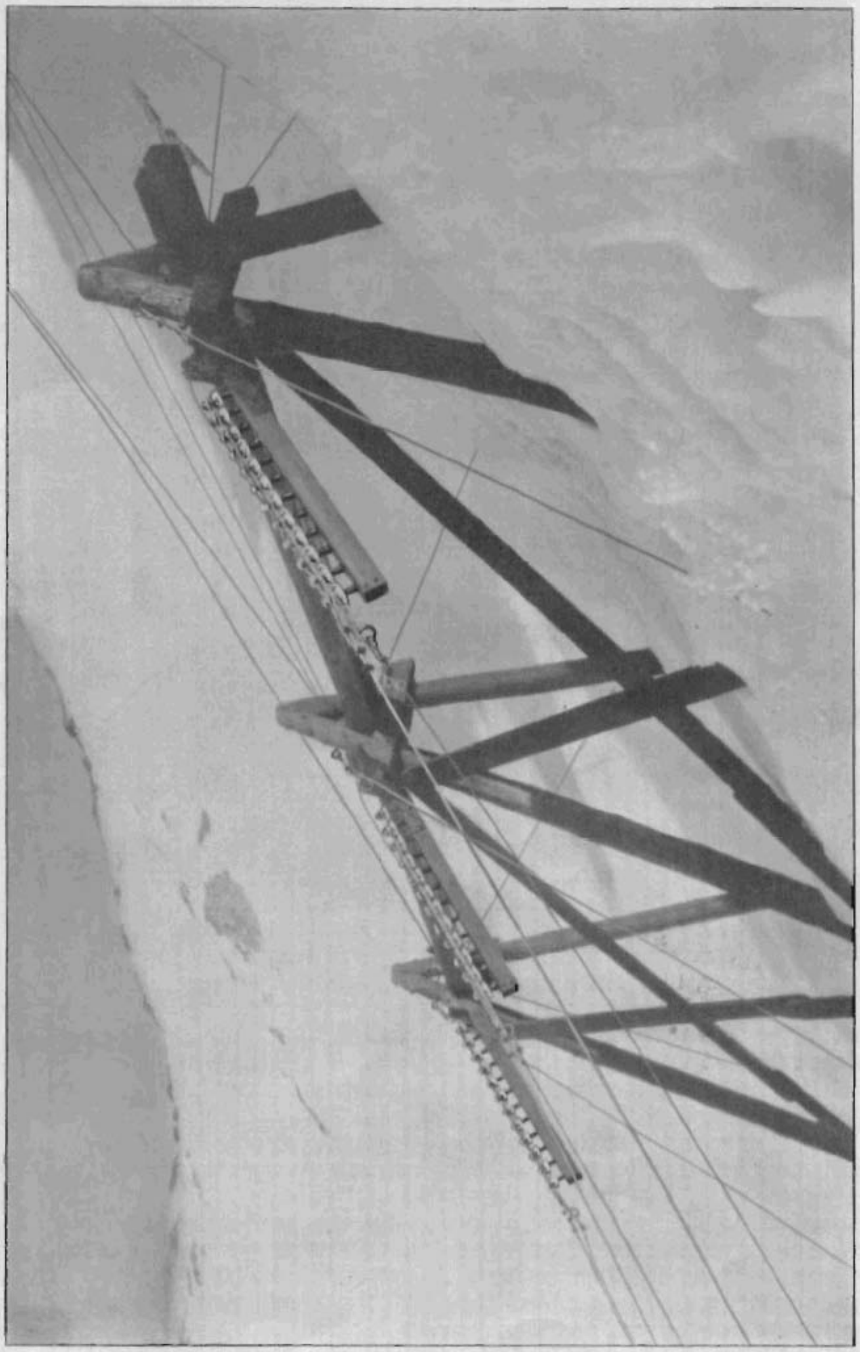
Two identical 75-kw., oil-insulated transformers were installed during the autumn of 1895, one at the Ames station and the other at the Gold King mill. They were designed for pressures rising from 15 000 to 60 000 volts by convenient steps. A separate pole line was equipped with three circuits of different characteristics mounted upon three types of insulators.

Measurements with many special instruments were made, embracing the different voltages, styles of insulators, conductors and effects of their separation, and the conditions peculiar to the various phenomena met at every step. Observations through a wide range of atmospheric conditions were made by means of United States Weather Bureau apparatus at either end of the line. The commercial feasibility of high pressures was demonstrated by the successful operation of the Gold King mill during a great part of the year, at pressures from 30 000 to nearly 60 000 volts, as well as by continuous electrification for nearly a month during dry weather, of a three-mile telephone circuit upon telegraph insulators, at pressures rising from 10 000 to 40 000 volts.

The change of the system from single to polyphase terminated actual transmission experiments. The reducing transformer was moved to the station, and another equipment designed for polyphase tests was ordered. The remaining time was devoted to open-circuit losses and to the verification of measurements previously made.



THE TOWER ON THE SUMMIT OF CAMP BIRD DIVIDE



A SIDE HILL SUPPORT IN EDGE OF SNOW SLIDE

SPECIAL CONSTRUCTION FOR SEPARATION OF CONDUCTORS

This work continued until August, 1897, when construction was begun upon the Provo plant.

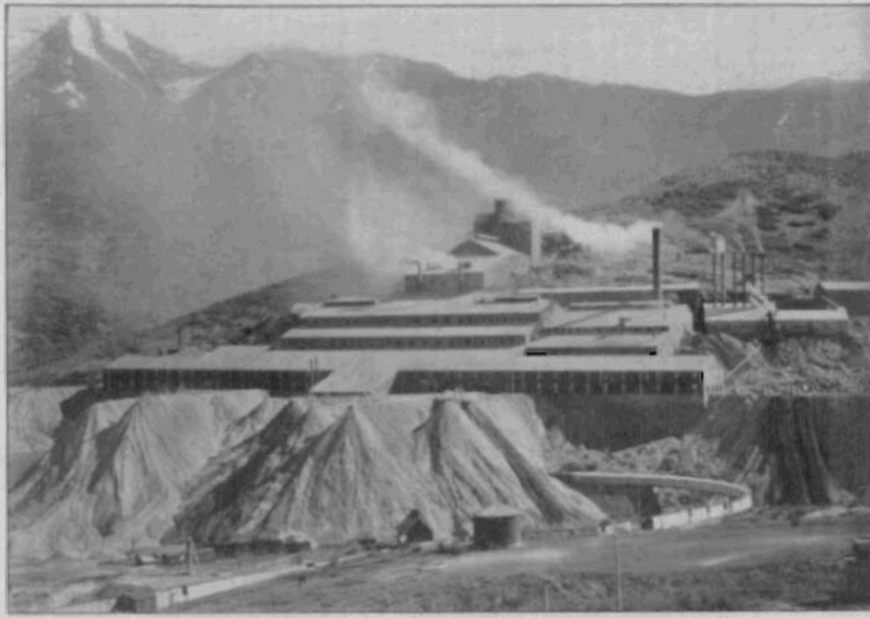
Much of the data obtained from these experiments was incomplete, requiring caution in its use, due largely to the time and study required in solving, step by step, the problems and difficulties met at every stage of the work. However, that much of value was obtained is shown by the subsequent successes at Provo. Sufficient had been learned to warrant the commercial adoption for the first time of 40 000 volts, nearly thrice the voltage of any previous plant, to lead to the manufacture of transformers which, after seven years' continuous operation, are still in daily service; to determine the design of the Provo-type insulator, the method of line construction, distance between wires, and the importance of wave form, and to make possible this great advance in long-distance, high-voltage transmission.

This experimental work, as clearly appears from the foregoing, was begun, carried on and finally utilized by The Telluride Company in the regular and necessary course of its growing business; yet it must be added that important services were rendered by Mr. V. G. Converse, under whose direction the transformers had been designed and constructed, and who participated throughout the greater part of the work, during all the experiments with actual high-pressure transmission; and subsequently by Mr. Ralph D. Mershon in the elaborate instrumentation and laboratory practice, including a notably ingenious method of reading high-tension losses upon low-tension circuits, devised by him and used in substantiating the accuracy of the earlier measurements; also, that different types of insulators were contributed by the General Electric and the Westinghouse companies and by Mr. Fred M. Locke on account of their friendly interest in the work. Moreover, great credit is due Mr. James Campbell, President of the Company, whose faith in the final result seems never to have wavered and without whose financial support success would have been impossible.

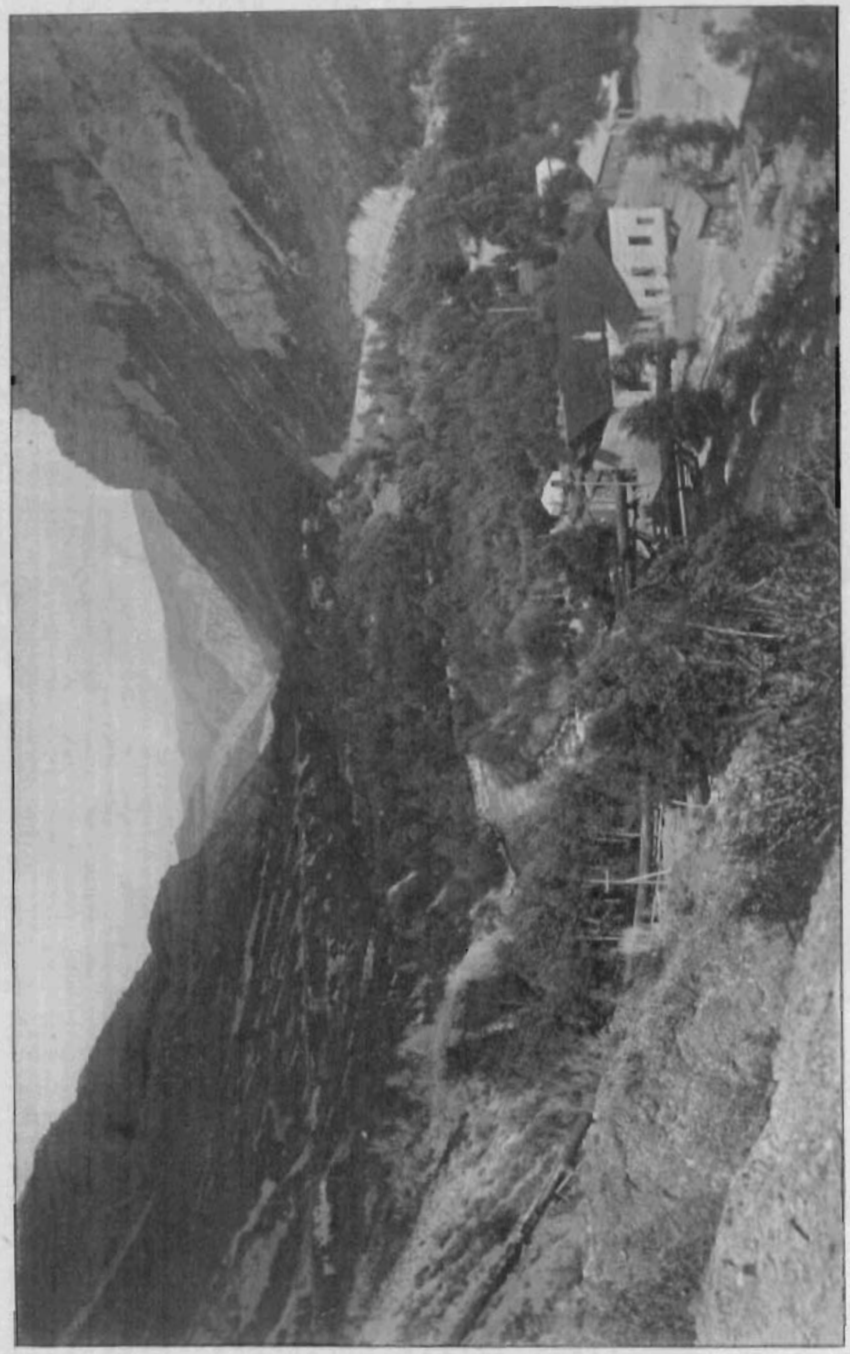
The original plant at Provo contained two 750-kw., 60-cycle, 800-volt, three-phase General Electric generators, direct connected at 300 rev. per. min. to twin horizontal turbines under 125-ft. head; a six-panel Wagner switchboard, two banks of oil transformers and two outgoing circuits. All contents thus in duplicate were assembled in two complete, independent units, designed for operation independently or in parallel at both high and low pressure. Prior to the power-factor indicator, a device which answered a somewhat similar purpose was installed, consisting of a wattmeter on the low-pressure paralleling bus, with current coil on one bus and shunt across the other two. This indicated cross current, and was used in the adjustment of field charges. Transformers were each 250-kw., 800 to 40 000 volts, star-connected at both high and low pressures, with neutrals grounded.

Triple-pole air switches and 4-ft. fuses formerly connected each bank of transformers with its transmission line. One form of air switch, opening six feet, containing no metal except conductors, was composed entirely of paraffined wood and rawhide, without porcelain, glass or other insulator. Others were sliding frames carrying line insulators.

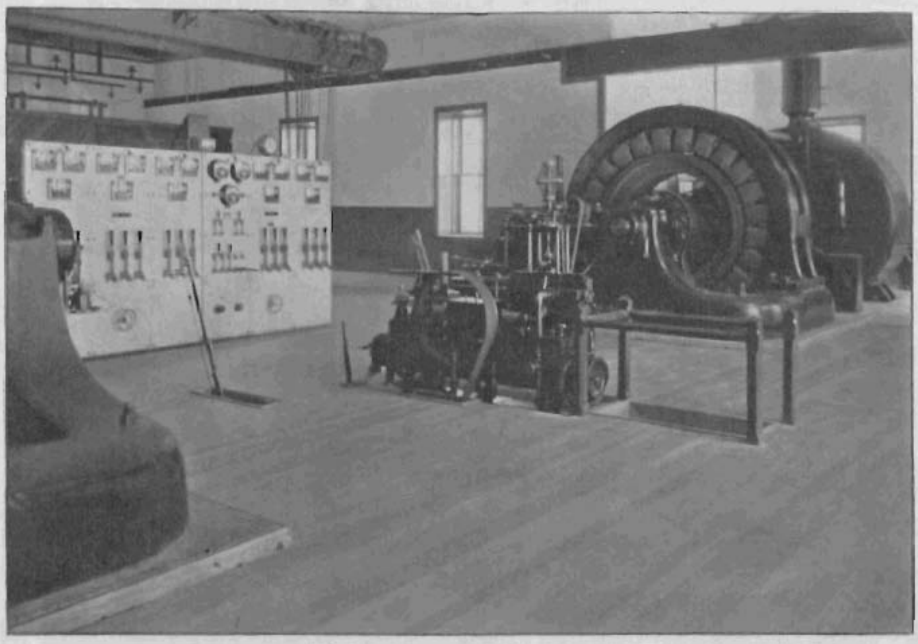
During the first year of operation the transmission comprised a single 32-mile line to one receiving point at Mercur, where the arrangement was similar to that at the power house, save that two reducing transformers were connected two-phase-three-phase, grounded neutral, for 220-volt two-phase induction motors. The Provo-Eureka line, 42 miles long, carries seven-strand aluminum cable equivalent to No. 4 copper. The Eureka-Mercur cross line, 28 miles long, of aluminum equivalent to No. 5 copper,



THE MERCER MILL, SUPPLIED WITH POWER FROM THE PROVO, UTAH, STATION, SHOWN ON PAGES 22 AND 23. THE FIRST INDUSTRY OPERATED BY 40,000-VOLT POWER



THE FIRST 40,000-VOLT POWER PLANT, PROVO, UTAH

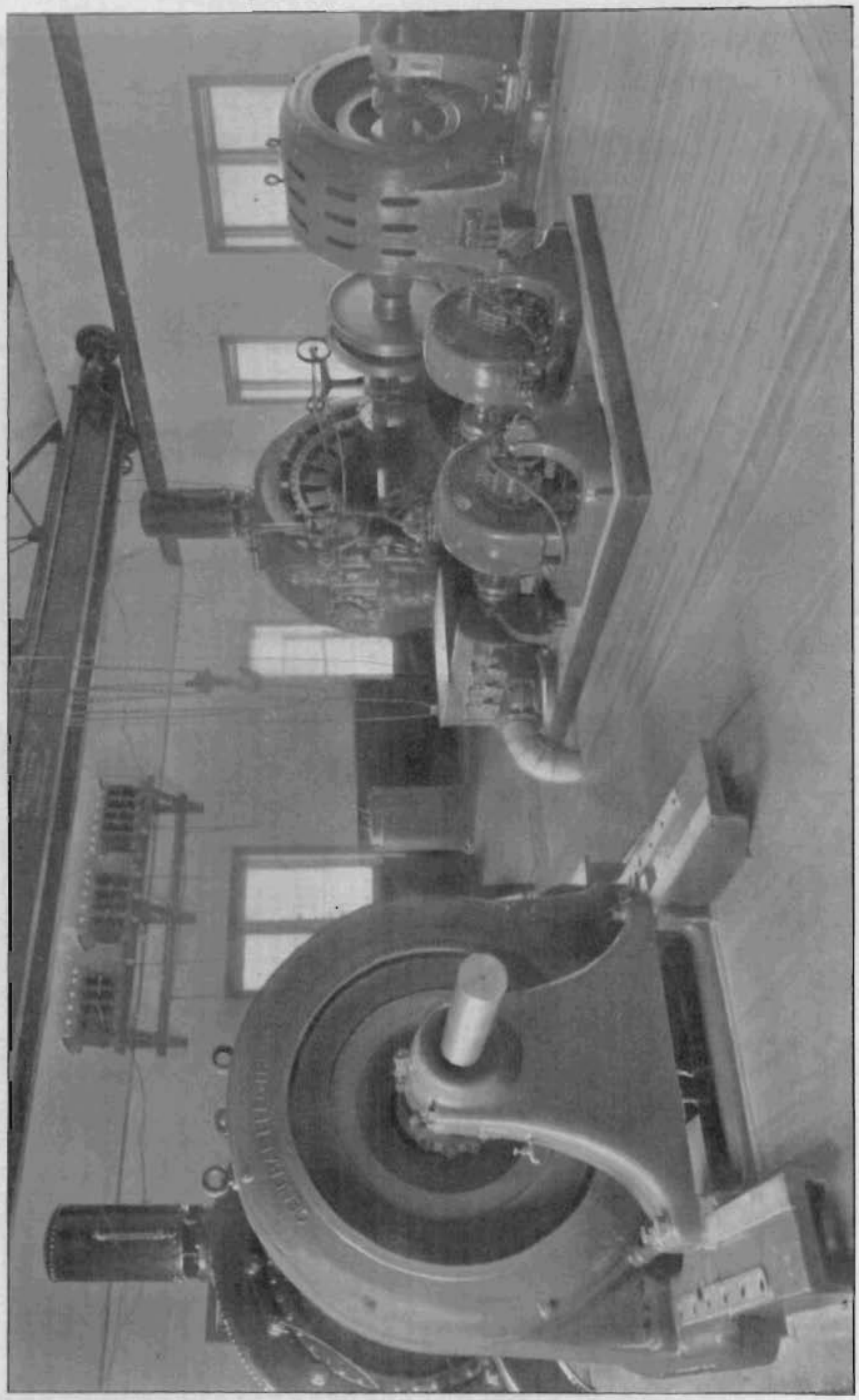


THE INTERIOR OF THE PROVO POWER HOUSE

was added to complete the triangle thus formed and to permit cutting out either of the three sides without interrupting service.

The Logan plant, completed in 1901, contains two 1 000-kw., revolving-field alternators direct connected at 400 revolutions to double-discharge twin turbines under 212-ft. head. This plant is connected with the Provo system by duplicate lines over 100 miles long, passing the cities of Ogden and Salt Lake. The Provo and Logan plants are thus operated in unison through nearly 200 miles of transmission. Distributing points at Mercur, Eureka, Bingham, Salt Lake and Provo are also junction points of the duplicate lines, equipped with switches in each incoming line as well as in circuit with the transformers, so that in case of threatened trouble a patrolman can, without delay, have his section cut off for immediate repair without interrupting service.

The three conductors of each transmission form an equilateral triangle 76 in. between wires, carried by a 7-ft. cross-arm and the top of the pole. Extra-long pins support the insulators 6 to 12 in. above cross-arms. They are of selected locust, kiln-dried and treated from six to twelve hours in hard paraffine at 150 deg. cent. Cross-arms are of Oregon fir, kiln-dried and soaked in boiling bitumen. Those upon the first line were attached in the usual manner with metal braces. The burning of cross-arms and poles on account of broken insulators, during prolonged wet weather, occurred most frequently at these braces. When the next lines were built in 1899, treated wooden braces were substituted, with results so favorable that they soon replaced all metal braces. It was still observed, however, that even slight leakage seemed to concentrate around the lag bolts, carbonizing the wood and finally loosening the bolts. For the Logan lines of 1900 and all later lines, therefore, the cross-arms were mortised through the poles and wedged and pinned with hardwood, thus discarding all metal except conductors. This construction was



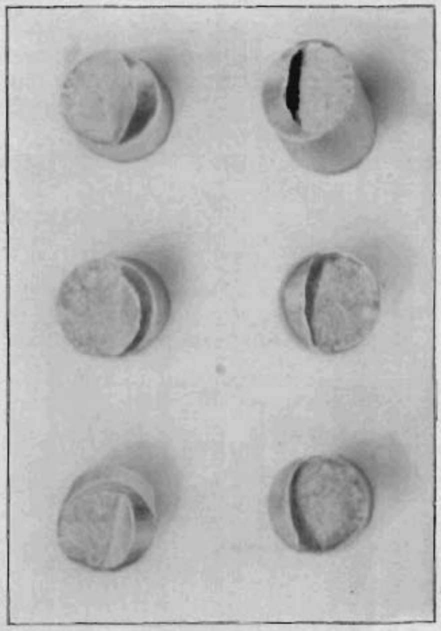
THE INTERIOR OF THE LOGAN POWER HOUSE

originated by Mr. A. L. Woodhouse, who, since the close of the high-pressure experimental work in Colorado of which he had charge, has been superintendent of the Utah department. It has proved amply strong, not expensive, and during the four years' operation of the 400 miles thus constructed very few poles have been burned.

Provo-type glass insulators, designed by Mr. V. G. Converse, have been used throughout. Many have broken, but these have usually shown the effects of guns or stones. In fact, there has not been a single breakage, except in one lot improperly annealed, clearly due to either internal or dielectric stresses. It is difficult to see wherein any other insulators could have done better, unless bullet-proof.

THE LOGAN POWER HOUSE

College laboratory tests to the contrary notwithstanding, leakage losses are inappreciable except during severest storms, and then not serious where insulators are unbroken. It is a mistake to suppose that Utah climate is favorable. During the rainy season it is as wet as any, and the alkali dust of the so-called salt storms is as trying as sea-coast spray. At times dense volumes of this impalpable dust from the Great Desert are accompanied by clouds or fog. In this damp, sticky state the dust completely covers, to a considerable depth, the under as well as the upper surfaces of insulators, as well as poles, cross-arms and pins. Over these surfaces streamers gradually creep until, meeting at the pole, they burst into a sheet of flame. A photograph of such an arc, taken

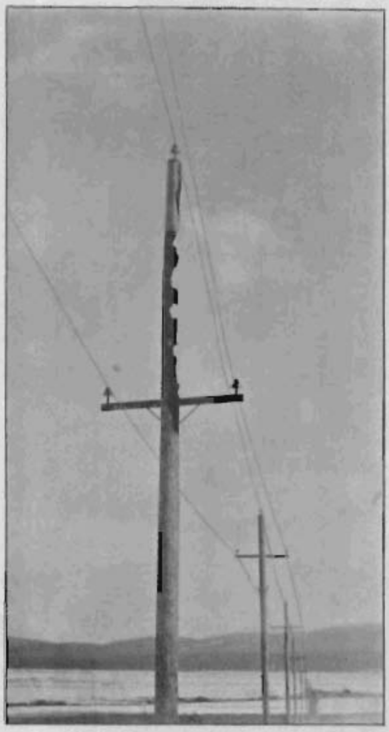


FRACTURE OF ALLOYED SOLID ALUMINUM CONDUCTORS

by Mr. C. E. Baker, the line patrolman at Mercur, has several times been published. A quick turn of the generator rheostat at the critical instant breaks the arc without interrupting service of induction motors.

The arrangement of power houses and transmission already described is such that the opening of paralleling switches may resolve the system into a single transmission from 100 to nearly 400 miles in length with a generator at each end, yet side by side. If one generator be reversed, synchronized as a motor with the other and loaded by its water wheel, any length of transmission, by manipulation of a paralleling switch, may be alternately cut in and out between them. Since switchboards and instruments are connected, and side by side, measurements are immediately comparable. In this manner losses and power factors may be measured, and the corrective effect of charging current observed.

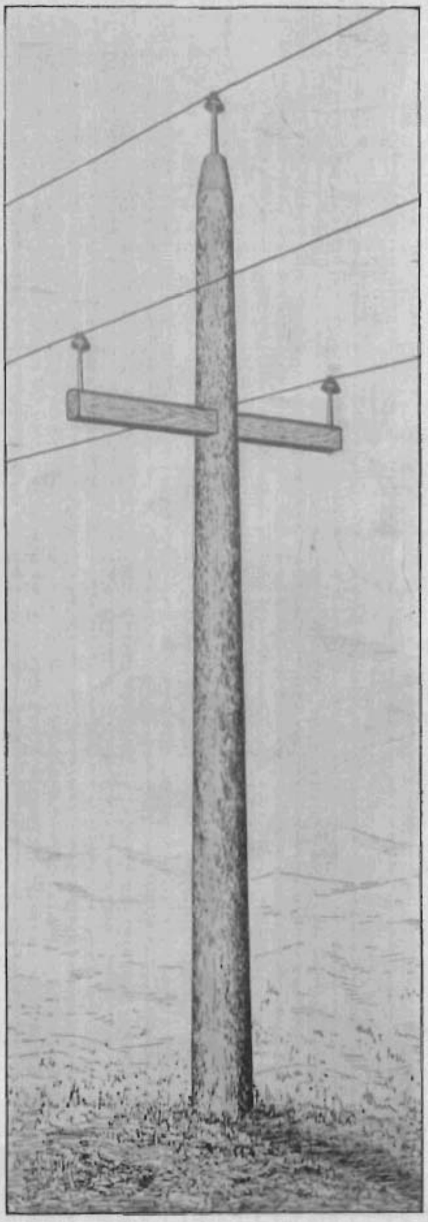
Solid aluminum wire, first used in



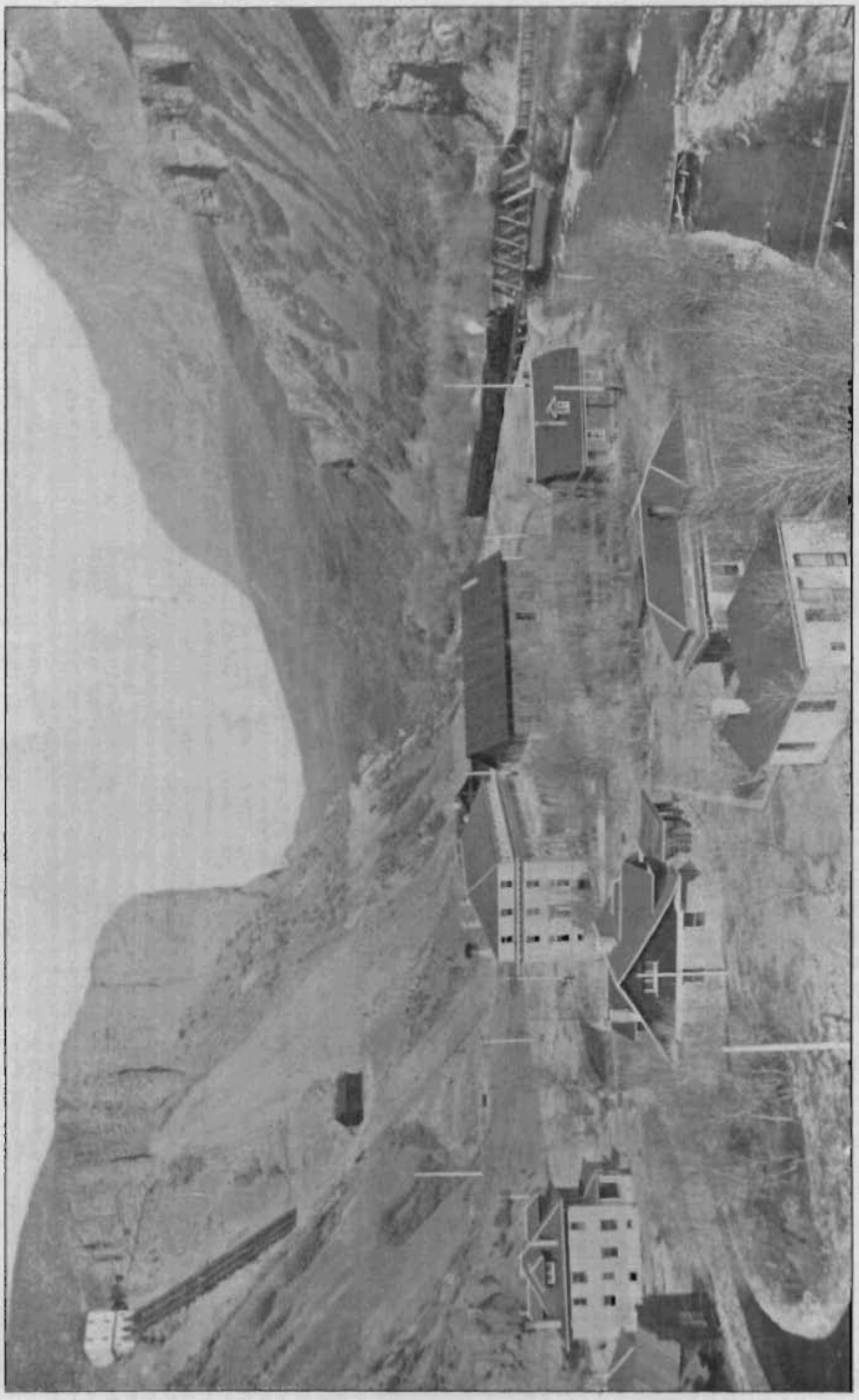
BURNT POLE OF EARLY CONSTRUCTION

1898, was slightly alloyed to increase strength, and proved worthless, breaking repeatedly with square, glass-like fractures. It was at once replaced with commercially pure, seven-strand cable, still in use. Similar cables have been employed generally for subsequent lines, while spans have been successfully increased to 180 and 200 ft., with less deflection than that usual with copper.

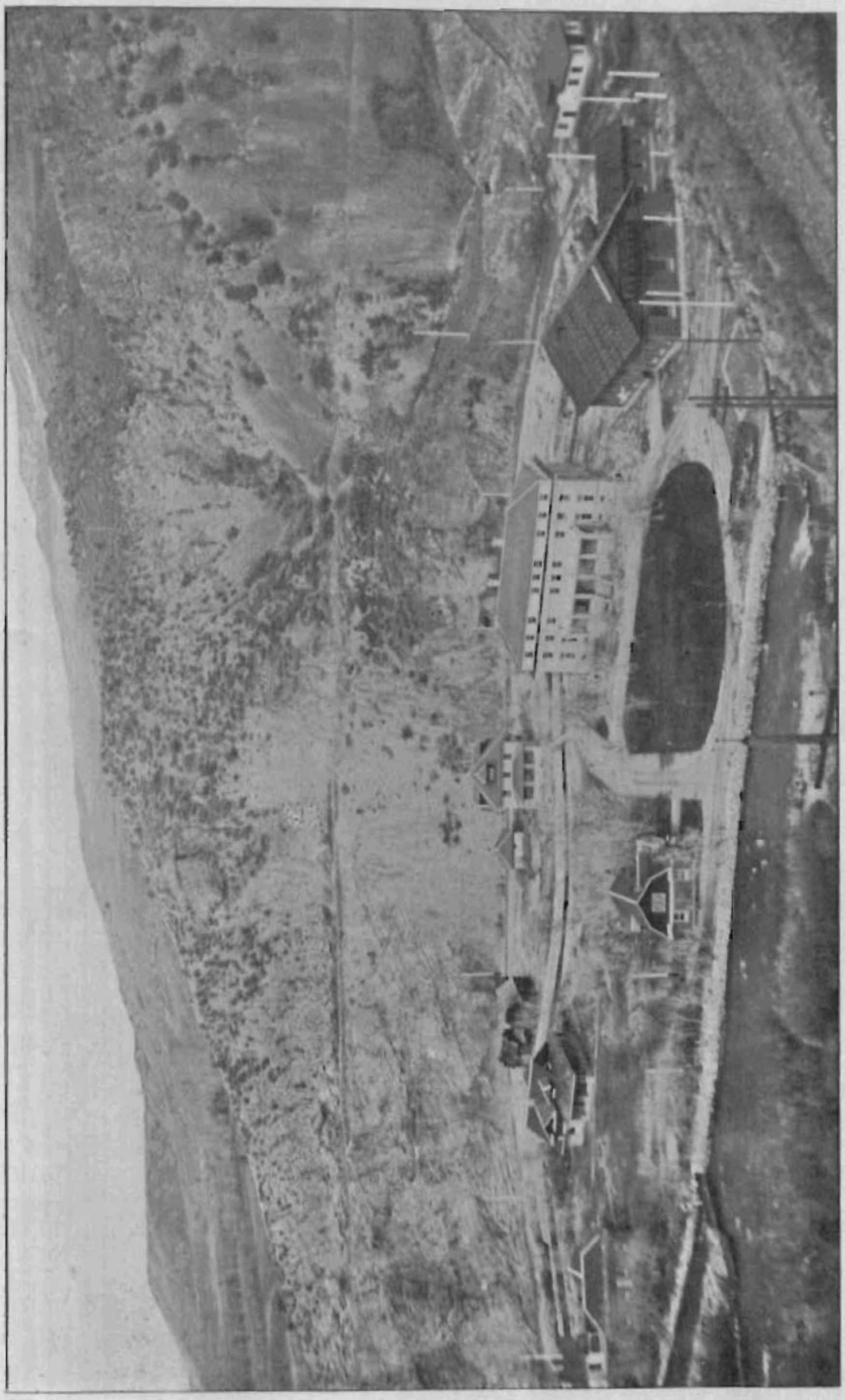
The experience with oil transformers for 10 000 volts at Telluride, and the refusal of manufacturers to give any guarantees whatever for other transformers for higher pressures, led the Telluride company, when undertaking this 40 000-volt transmission, to manufacture its own. The first equipment, made at the Wagner company's works, was designed and constructed by Mr. Converse. The later ones were made by The Converse Transformer Company. When erected, the oil in the tank and the transformer in an oven were slowly raised to a temperature of 125 deg. cent. and there maintained for 24 hours. The transformer was then immersed in the oil, and both held at the same temperature for a further 24 hours. As bearing upon



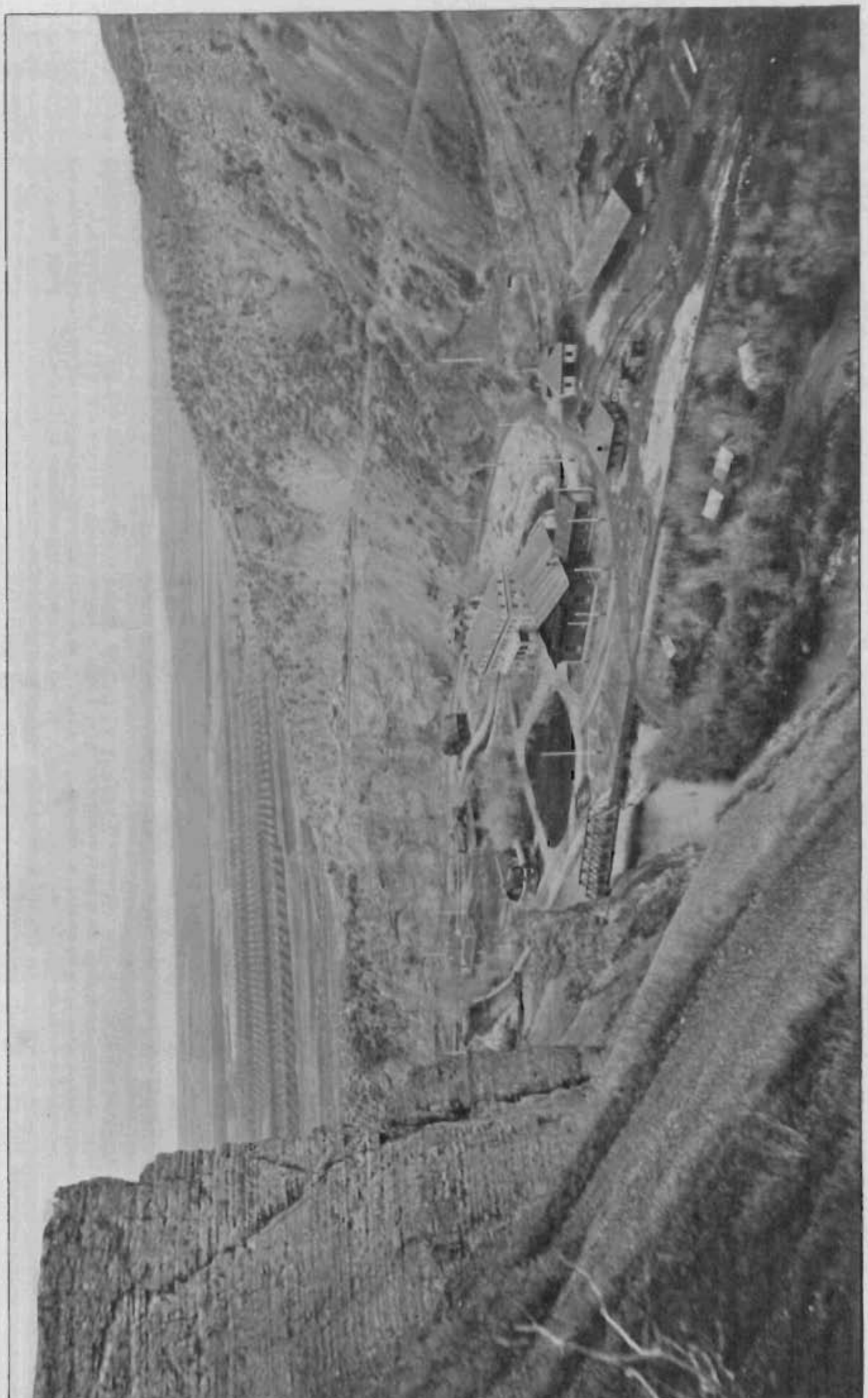
PRESENT ALL-WOOD POLE CONSTRUCTION



GENERAL VIEW OF OLMSTED, LOOKING EAST, SHOWING NEW PROVO POWER HOUSE AND INSTITUTE BUILDINGS



OLMSTED AS SEEN FROM THE SOUTH HILLS



UTAH VALLEY AND LAKE AS SEEN FROM PROVO CANYON the fire risk due to oil transformers, it may be of interest to note that of the large number of these high-pressure transformers used during the past seven years, chiefly in isolated sub-stations containing much wood and seldom visited, all but four are still in operation; that these four were destroyed by fire of doubtful origin, and that only one has required repair other than change of oil.

The plant at Norris, Montana, designed and constructed in 1901, by Mr. O. B. Suhr, Superintendent, (now resident engineer of the Ontario Power Company) contains at present two low-speed, 1 000-kw. units. A duplicate transmission of 60 miles conveys power to the city of Butte. These lines as well as both raising and reducing transformers were designed for the use of 40 000, 60 000 or 80 000 volts. Longer pins are used than in Utah, and conductors form a triangle of 108 in. While producing the present limited amount of power and awaiting a suitable insulator, the lower voltage has been used.

In conclusion, it may be said that the Provo plant, the first transmission at more than 16 000 volts, while undertaken materially in advance of the art, and not exempt from its share of troubles, has, nevertheless, been fully successful as a financial venture, and not without value in the progress of the science.

Long periods of perfect operation, monotonous in their uneventfulness, have proven beyond question the success of high pressures for long distances. The new and larger power house at Olmstead, at the mouth of Provo Canyon, completed this season, is modern in every detail. It contains three 3 600-h.p. generators operating under 340 ft. head. Air switches and fuses are everywhere giving place to oil switches with time-limit automatics, and constant reconstruction to meet its increasing demands keeps the system as a whole abreast of present practice. Thus The Telluride Power Company, while again and again a pioneer in power transmission, must not be associated alone with the experimental methods of early days, but may, in future, be found still engaged in progressive, practical pioneer work.